On the changing roles of neuroimaging in rehabilitation science

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Advances in neuroimaging have clearly changed the way that human brain function, dysfunction, and rehabilitation are being conceptualized and studied. In addition to complementing existing behavioral and psychometric approaches to rehabilitation research, advanced imaging technologies, as well as innovative approaches to analyzing data derived from established procedures, have allowed for novel inferences that cannot necessarily be made through other approaches to studying brain-behavior relationships. While early work focused on the diagnostic value of neuroimaging, the prognostic value of biomarkers derived from imaging data is gaining traction. Critically, neuroimaging data are proving valuable in efforts to identify mechanisms that underlie dysfunction and mediate therapeutic responses. Early signs give us hope that such mechanistic insights will catalyze a new generation of more targeted, neurally inspired interventions and enable better individualization of treatment strategies.

This special issue of *Brain Imaging and Behavior* provides a forum for the integration of state-of-the-art neuroimaging technologies with rehabilitation and is both timely and

critically important. Unprecedented media attention is being devoted to the needs of rehabilitation populations, particularly in light of traumatic brain injuries among soldiers that have returned from deployment in the Middle East over the past decade, as well as increased attention to concussion and stroke. The three populations represented in this issue's original contributions and review articles are stroke, multiple sclerosis (MS), and traumatic brain injury (TBI). These populations are of particularly critical importance in terms of economic impact and rehabilitation needs, as each is among the leading causes of disability in adulthood worldwide.

The four stroke studies use MRI-based imaging techniques to investigate prognosis and mechanisms of recovery as well as a variety of rehabilitation domains and methods. Wittenberg and colleagues use fMRI to study post-stroke cerebral correlates of skills needed for dressing. Chen et al. demonstrate how the functional integrity of medial temporal lobe structures can be predicted from the effectiveness of prism adaptation treatment following stroke. Boespflug et al. utilizes DTI as a biomarker for response to motor rehabilitation using electrical stimulation. The study by Harnish and colleagues employs fMRI to explore the interrelatedness between language and motor changes involved in rehabilitative therapy for hemiparesis.

Each of the studies from the multiple sclerosis population uses MRI-based neuroimaging to examine cognition, including three separate clinical trials of cognitive rehabilitation. The study from Nocentini and colleagues applies voxel-based morphometry to explore brain-behavior correlates across a large battery of standardized neuropsychological tests. Parisi et al. examine resting state functional connectivity fMRI before and after computer-assisted cognitive rehabilitation in a randomized controlled investigation. Leavitt and colleagues also examine resting state functional connectivity in a controlled trial, but utilized a behavioral rather than computer-based intervention. The investigation from Dobryakova and

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colleagues uses fMRI to examine the effects of memory rehabilitation at six months after treatment in persons with MS.

There are three studies and two review articles addressing traumatic brain injury. Marquez de la Plata and colleagues compare three functional connectivity methods for examining the default mode network (DMN) and cognitive status after traumatic axonal injury. The review by Weaver et al. provides a critical examination of genetic polymorphisms that are associated with neurocognitive and psychosocial impairment and recovery after TBI. The study from Hillary's group employs effective connectivity MRI and structural equation modeling to examine learning trajectories in persons with TBI. Rodriguez Merzagora and colleagues present a study of working memory performance using functional near-infrared spectroscopy (fNIRS). Finally, Neumann et al. review the neuroimaging literature on the processing of facial affect and how previous findings may guide future research and intervention in persons with TBI.

The articles in this special issue of *Brain Imaging and Behavior* represent a sampling of the diverse questions that are being addressed with advanced imaging techniques, and will by no means be the last word on neuroimaging in rehabilitation. Neuroimaging will continue to advance, and new technologies are being developed. The same may also be said for novel approaches to both physical and cognitive rehabilitation. Investigations of the human “connectome” have only recently been extended into neurorehabilitation populations and are likely to offer further insight into the brain's response to injury, illness and rehabilitation. Although not represented in this issue, radioligand-based technologies such as positron emission tomography (PET), and electrophysiological approaches such as magnetoencephalography (MEG), will also offer unique insights into the correlates and substrates of neural rehabilitation. New genetic and other biomarkers are continuously under development and will also contribute to the knowledge base. Neuroimaging and other complementary tools are facilitating the personalized rehabilitation diagnostics and therapeutics of the future.